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**EARLY MARS: A REGIONAL ASSESSMENT OF DENUDATION CHRONOLOGY.** T. A. Maxwell and R. A. Craddock, Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington DC 20560, USA.

Within the oldest highland units on Mars, the record of crater degradation indicates that fluvial resurfacing was responsible for modifying the Noachian through middle-Hesperian crater population [1]. Based on crater frequency in the Noachian cratered terrain, age/elevation relations suggest that the highest exposures of Noachian dissected and plateau units became stabilized first, followed by successively lower units [2]. In addition, studies of drainage networks indicate that the frequency of Noachian channels is greatest at high elevations [3]. Together, these observations provide strong evidence of atmospheric involvement in volatile recycling. The long time period of crater modification also suggests that dendritic highland drainage was not simply the result of sapping by release of juvenile water, because the varied geologic units as well as the elevation dependence of stability ages makes it unlikely that subsurface recycling could provide a continuous supply of water for channel formation by sapping. While such geomorphic constraints on volatile history have been established by crater counts and stratigraphic relations using the 1:2M photomosaic series, photo-geologic age relationships at the detailed level are needed to establish a specific chronology of erosion and sedimentation. Age relations for discrete erosional slopes and depositional basins will help refine ages of fluvial degradation, assess effectiveness of aeolian processes, and provide a regional chronology of fluvial events. In particular, are stratigraphic relations between dissected plateau units and neighboring plains (usually lumped on small-scale mapping) consistent with a local source/sink scenario for fluvial deposits? Can age relations be determined for discrete depositional basins [e.g., 4] and their neighboring eroded highlands? Did individual degradation events last long enough to be resolved by the cratering record?

One of the long-standing problems in martian geomorphology has been the unique identification of fluvial deposits either within the northern plains [5,6] or elsewhere in the debouchment regions of channels. However, in the low-latitude highlands, sedimentary deposits occur within enclosed basins [4], at areas of channel constriction, and within impact craters. These materials typically consist of subdued, polygonal mesas 2–10 km across, are morphologically similar to the fretted terrain of the Nilosyrtris Mensae region [7], and are laterally confined. Where these deposits are present within degraded craters, the host crater is typically breached by either a through-going or terminating channel. Unfortunately, these units are not extensive enough to allow crater age determinations, so their ages must be inferred by stratigraphy and the age of the superposed surface. Later periods of volcanism and airfall deposition [8] have probably buried many of these deposits, but their distribution suggests that the original sedimentary cover of the martian highlands was once more extensive than is now represented by the few scattered outliers.

In contrast to depositional surfaces, erosional surfaces in the highlands are much more easy to date. There the record of degraded craters indicates the combined effects of erosion from the Noachian through mid Hesperian. The fresh crater population can be used to tell when such surfaces were no longer subject to earlier intense

erosion. In the absence of discrete, datable deposits, such erosion surfaces are being used to determine the timing of Mars denudation.

**References:** [1] Craddock R. A. and Maxwell T. A. (1990) *JGR*, 95, 14265–14278. [2] Craddock R. A. and Maxwell T. A. (1993) *JGR*, 98, 3453–3468. [3] Dohm J. M. and Scott D. H. (1993) *LPS XXIV*, 407–408. [4] Goldspiel J. M. and Squyres S. W. (1991) *Icarus*, 89, 392–410. [5] McGill G. E. (1986) *GRL*, 13, 705–708. [6] Lucchitta B. K. et al. (1986) *Proc. LPSC 17th*, in *JGR*, 91, E166–E174. [7] Sharp R. P. (1973) *JGR*, 78, 4073–4083. [8] Grant J. A. and Schultz P. H. (1990) *Icarus*, 84, 166–195.

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**EARLY MARS WAS WET BUT NOT WARM: EROSION, FLUVIAL FEATURES, LIQUID WATER HABITATS, AND LIFE BELOW FREEZING.** C. P. McKay and W. L. Davis, NASA Ames Research Center, Moffett Field CA 94035, USA.

There is considerable evidence that Mars had liquid water early in its history and possibly at recurrent intervals. It has generally been assumed that this implied that the climate was warmer as a result of a thicker CO<sub>2</sub> atmosphere than at the present. However, recent models suggest that Mars may have had a thick atmosphere but may not have experienced mean annual temperatures above freezing. In this paper we report on models of liquid water formation and maintenance under temperatures well below freezing.

Our studies are based on work in the north and south polar regions of Earth. Our results suggest that early Mars did have a thick atmosphere but precipitation and hence erosion was rare. Transient liquid water, formed under temperature extremes and maintained under thick ice covers, could account for the observed fluvial features. The main difference between the present climate and the early climate was that the total surface pressure was well above the triple point of water.

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**WET INSIDE AND OUT? CONSTRAINTS ON WATER IN THE MARTIAN MANTLE AND ON OUTGASSED WATER, BASED ON MELT INCLUSIONS IN SNC METEORITES.** H. Y. McSween Jr. and R. P. Harvey, Department of Geological Sciences, University of Tennessee, Knoxville TN 37996, USA.

Constraints on the volatile inventory and outgassing history of Mars are critical to understanding the origin of ancient valley systems and paleoclimates. Planetary accretion models for Mars allow either a volatile-rich [1] or volatile-poor [2] mantle, depending on whether the accreted materials were fully oxidized or whether accretion was homogeneous so that water was lost through reaction with metallic iron. The amount of water that has been outgassed from the interior is likewise a contentious subject, and estimates of globally distributed water based on various geochemical and geological measurements vary from a few meters to more than a thousand meters [3]. New data on SNC meteorites, which are thought to be martian igneous rocks [4], provide constraints on both mantle and outgassed water [5].

—The bulk water contents of SNC meteorites, measured after precombustion to remove terrestrial contaminants, are small, in the range of 130–350 ppm. However, because of low internal pressures on Mars, ascending magmas are subject to vesiculation, and they